Research Report

First Order Analysis as CAE for Design Engineers

Yoshio Kojima

Abstract

CAE (Computer Aided Engineering) has been regarded as a numerical experiment to replace prototyping and experiments. Moreover, the necessity for designers' CAE has recently come under discussion. This refers to the CAE that covers processes such as product planning and grand design. This paper will introduce FOA (First Order Analysis) software as the designers' CAE and address how it can work in the future.

Keywords Automobile, Structure, Mechanism, Design, CAD, CAE, FOA

1. Introduction

Nowadays, movies make heavy use of computer graphics (CG), but we no longer show much interest in the reality of graphics themselves, instead enjoying the scenes that they are used to produce. Similarly, with Computer Aided Engineering (CAE), we expect it to reproduce situations faithfully. Needless to say, most people think that this development effort should continue in its current direction, instead the main issue has shifted to the start point of that engineering. CAE has come to be recognized as an engineering technique, or a manufacturing support system that incorporates mechanical design technology for ensuring light weight and high stiffness, production technology for quickly bringing products to market to satisfy the needs of users, and manufacturing technology for providing high-value products at the lowest possible cost.

This paper shows how CAE should be applied in the planning and design stages, and gives First Order Analysis as an example.

2. The expanding roles of CAE

In 1980, Computer Aided Engineering (CAE) was advocated in the United States as a means of supplying analysis information in a timely manner in the design and manufacturing fields, thereby enabling huge improvements to be made to existing products through the application of unprecedented new techniques.[1)] Later, in the United States, much research was done on the strength of manufacturing industry in Japan. A typical example is that developed at MIT and which came to be known as Lean Production.[2)] Among the engineering ideas derived from that is Concurrent Engineering,[3)] which appeared at the beginning of the 1990s. This advocated a change from the normal approach in which development processes such as product design, testing, and manufacturing were sequential, to situation in which the processes overlapped. We have seen cases in which the use of Concurrent Engineering, as typified by design and production techniques such as Design for X[4)] and Agile Manufacturing,[5)] enables the commercialization of products in a very short time, including mold development; the commercialization of cellular phones, which undergo model changes every few months, is an excellent example of this. These cases can be regarded as successful attempts to apply CAE to the prototype, experiment, and evaluation stages, backed by recent improvements in computer hardware.[6)]

Advances in computer hardware have made it possible to provide design engineers with advanced three-dimensional graphics capabilities on personal 3D-CAD (Computer Aided Design) systems. Using these capabilities, design engineers can execute CAE while performing drawing with CAD. We now have access to an environment in which individual design engineers can handle advanced CAE at the design stage.

3. CAE for design engineers

3. 1 CAD-embedded CAE

Using a 3D-CAD system, design engineers can draw product shapes in the similar way as when drawing CG. Thus, thanks to CAE, design engineers can easily calculate stress distributions and deformations without having to be aware of the modeling process. The leading CAE vendors have started to offer CAD system software with built-in CAE functions (CAD-embedded CAE).[7, 8)] If a parameter study of the design variables is done in the same way as for numerical prototyping, an optimization technique using, for example, design of experiment/response surface method (DOE/RSM)[9)] can be used to easily achieve shape optimization in the allowable design domain. It is expected that this type of CAE for design engineers will continue to undergo functional improvements in the future while retaining conventional, powerful, and general-purpose CAE functions as a solver.

Just as the digitization of production technology in the final stages of development has spread with the adoption of numerical control (NC) machine tools, the digitization of the design stage in the first stages of development will be embodied and established with the emergence of 3D-CAD.

3. 2 First Order Analysis

CAD-embedded CAE is used for certain roles in the design process. It does not always, however, have the ability to preserve and inherit creative activities, such as planning and concept design, and design know-how. This is because the current types of CAD-embedded CAE are based on conventional CAE procedures in which a shape is first determined and then analysis is performed, and are lacking in that they cannot be used to establish a concept before the start of modeling.

To solve this problem, we have been investigating First Order Analysis (FOA).[10, 11)] Our attempts have consisted of the following:

(1) Pre-product shape template function
(2) Spreadsheet function that allows a product to be divided into parts
(3) Performance calculation function that can be specialized for each part
(4) Function for calculating the properties of a product made by combining parts
(5) Part shape and design parameter optimization function

By using FOA, design engineers can "brainstorm" in accordance with the design procedure and, if they devise an interesting idea, can confirm it immediately. The design procedure, as described here, includes techniques incorporating the mechanics of materials and others for extracting only the information necessary for design from the results obtained with "numerical" CAE. Many of these techniques are the intellectual property of experienced design engineers who have been performing product design for a long time, and which FOA tools can be said to have digitized. For individual examples and the measures used for developing tools, see the respective explanations in this special issue.

The most important uses of FOA are the setting of concepts before the start of modeling and in quickly determining which of several plans is best, using a knowledge of dynamics. If it is of the most importance that numerical experiment CAE, as well as CAD-embedded CAE that is oriented toward design engineers and based on it, approximate actual phenomena, the main focus of FOA is to closer mimic the thinking processes of design engineers and drawing procedures.

4. Design engineers' CAE for the future

If design engineers' CAE will be used to handle problems related to strong non-linearity and unsteady in the future, it will be necessary to start by re-examining the process by which design engineers should design non-linearity and unsteady phenomena and replace them with product shapes. When the hierarchy of FOA is specialized for products, the phenomena that can be handled are also specialized, and it is thought that they can be embodied using FOA tools. This functionality may be provided as an optional function of CAD-embedded CAE.

Basically, upon the original shift from the drawing board to two-dimensional CAD, the conventional front, side, and top views were merely digitized; little thought was given to the fact that design know-how would be scattered and lost. For the 3D-CAD of the future, the ways in which shapes are created may change. Modern-day expectations for design engineers' CAE are set against an underlying anxiety as to how to preserve and inherit the know-how that has been behind the reliability of products.

5. Conclusions

Advances in CAE have begun to bring about changes in the manufacturing environment, and the opportunities to enjoy its advantages have increased. On the other hand, it cannot be denied that reducing the number of physical prototypes reduces the opportunities to learn from the real objects. If FOA can present one solution to this problem, it can be said that our attempts have been a success. In addition, if FOA makes design engineers feel more comfortable with the planning and design of structures and mechanisms, the opportunities to impress others with their ideas will increase.

It would be a pleasure for us, being involved in the study of FOA if, in promoting the application of CAE, we can expand the concept of design engineers' CAE in the world of engineering to create new businesses, after going through the stage of "merely" promoting labor-saving in the name of efficiency.

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(Report received on Dec. 21, 2001)

Yoshio Kojima
Year of birth : 1958
Division : Research-Domain 14
Research fields : CAE for design engineers
Academic degree : Dr. Eng.
Academic society : Jpn. Soc. Mech. Eng., Soc. Automot. Eng. Jpn.
Awards : R&D 100 Award in 1991